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71 Applicant: **UNITED TECHNOLOGIES CORPORATION**  
**United Technologies Building 1, Financial Plaza**  
**Hartford, CT 06101 (US)**

72 Inventor: **Ginnis, Andrew F.**  
**298 Cedar Ridge Drive**  
**Glastonbury Connecticut 06033 (US)**

**Larkin, Wesley F.**  
**18 Dawn Drive**  
**South Windsor Connecticut 06074 (US)**

74 Representative: **Waxweiler, Jean et al**  
**OFFICE DENNEMEYER S.à.r.l. P.O. Box 1502**  
**L-1015 Luxembourg (LU)**

54 **Transient holographic indication analysis.**

57 A method of holographic analysis of an article is disclosed. The method involves generating holograms of an article to be analyzed and a reference article over a range of excitation energy levels and comparing the features of the holograms so generated to characterize the material and structural properties of the article.

FIG. 1A

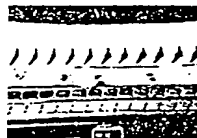
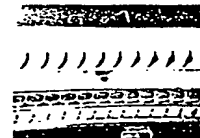


FIG. 1B



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## Description

### Transient Holographic Indication Analysis

#### Technical Field

The field of art to which this invention pertains is non-destructive testing by means of holographic analysis.

#### Background Art

Time average holography is a technique which applies holographic interferometry to the study of the surface deformation of vibrating objects. The technique involves photographically recording the interference pattern between a coherent light source and light reflected from a vibrating object illuminated by the coherent light. U.S. Patent No. 3,645,129 and commonly assigned U.S. Patent No. 4,408,881 disclose methods for testing the integrity of bonded joints between two members by time average holography. The above cited disclosures are incorporated herein by reference. In each of these methods a hologram of the bonded joint is generated while the joint is being vibrated. If there is a discontinuity in the bond, the two members vibrate independently of each other and a number of superimposed interference fringes appear against the background of the hologram as a contrasting area. The method is useful as a non-destructive quality control test for articles having bonded joints.

In practice the method has been found to be unreliable in some applications because of an inability to distinguish between indications associated with disbands and those associated with other causes. Consequently, a significant number of false positive readings may result from the conventional method.

#### Disclosure of the Invention

A holographic analysis method is disclosed. The method involves generating, at different excitation energy levels, a series of holograms of an article and of a reference article which contains a known anomaly, comparing the holograms, and analyzing the differences between the holograms to characterize the material and structural properties of the article.

The foregoing and other features and advantages of the present invention will become more apparent from the following description and accompanying drawings.

#### Brief Description of the Drawings

FIG 1A is a hologram of a reference article at a high excitation energy level.

FIG 2A is a hologram of a reference article at an optimal excitation energy level.

FIG 3A is a hologram of a reference article at a low excitation energy level.

FIG 1B is a hologram of a test article at a high

excitation energy level.

FIG 2B is a hologram of a test article at an optimal excitation energy level.

FIG 3B is a hologram of a test article at a low excitation energy level.

#### Best Mode for Carrying Out the Invention

The holographic analysis method of the present invention is useful for quality control of a series of similar articles. In the best mode embodiment shown a reference article which contains a known material anomaly that has been independently characterized, is used to generate at least two reference holograms. The first reference hologram is generated according to the conventional method of holographic analysis. The reference article is caused to vibrate by the application of an excitation energy. Excitation energy may be applied by, for example, a piezoelectric shaker. The excitation energy level and thus the intensity of vibration applied to the reference article will vary in different situations and must be experimentally determined for each particular type of article and particular test apparatus. It is preferable to use a force that will excite the disbonded areas, but which will impart very small amplitudes to the resonant modes of the test object, so that defects in the bond will stand out with maximum clarity. A first energy level is determined which reveals a clearly defined indication of the reference anomaly that is in strong contrast to the background. Once the energy level which shows the clearly defined and strongly contrasting indication of the reference anomaly is found, the analysis continues according to the present invention.

According to the present invention, at least two and preferably three or more reference holograms are generated. A second reference hologram of the reference article is generated at a second excitation energy level that is below the first energy level. The second excitation energy level is chosen such that the indication of the anomaly is just visible against the background. It is preferred that the second excitation energy be determined systematically, as for example, by evaluating the effects of incremental decreases in excitation energy level until the indication of the anomaly disappears. The excitation energy level is then increased slightly until the indication is visible against the background. The excitation energy level at which the indication again becomes detectable would correspond to the preferred second excitation energy level.

It is preferred that three holograms be generated each at a different excitation energy level and particularly preferred that a plurality of holograms be generated across a spectrum of excitation energies so that a relationship may be developed between the rates of change of characteristics of the indication of the anomaly, most importantly the shape, size, edge definition and contrast of the indication, as a function of excitation energy. The relationship so

developed may then be correlated to characterize the specific anomaly of interest.

The number of holograms necessary to develop sufficient information to characterize a particular anomaly with confidence will depend upon the particular nature of the article and of the anomaly.

If holograms are generated at more than two excitation energy levels, it is preferred that the third hologram be generated at an excitation energy level above the first excitation energy level yet below an excitation energy level that results in a loss of contrast of the indication due to excessive background noise. The third excitation energy level is determined in a manner similar to that used to determine the second excitation energy level. It is preferred that the third excitation energy level be determined systematically, as for example, by evaluating the effects of incremental changes from the first energy level to that energy level at which the indication becomes difficult to distinguish due to the loss in contrast caused by excessive background noise. The preferred third energy level would correspond to that energy level just lower of that causing the excessive background noise.

Once the reference holograms have been generated, analysis of the test article may proceed. A hologram of the article is generated at the first excitation energy level and the hologram is examined to determine if it contains an indication of an anomaly in the article. If no indication is apparent, the article need not be further examined. If the hologram at the first energy level reveals an indication of an anomaly in the article, a second hologram of the article is generated at the second energy level. If a plurality of reference holograms each corresponding to different excitation energy levels are available, then a plurality of holograms of the test article may be generated at energy levels corresponding to those used in the reference holograms.

The holograms so generated are compared to each other to evaluate the transient nature of the appearance of the indication. The key features of the indication are the geometry and intensity of the indication. Changes in the shape and intensity of the indication and particularly changes in the distinctness of the edge of the indication as well as differences in the rate at which the changes in the indication occur relative to the changes in excitation energy are analyzed to determine the probable cause of the indication. The probable cause may be determined by comparing the differences in response of the indication in the hologram of the test article with changes in excitation energy levels to the response of the indication in the holograms of the reference article with changes in excitation energy levels.

For example, in the case of a bonded fiber metal abrasible seal, conventional holographic analysis produces holograms in which the indication associated with a discontinuity in the bonded joint cannot be readily distinguished from an indication associated with a variation in the density of the porous fiber metal material. The distinction is important because density differences are acceptable for a quality control standpoint, while discontinuities in the bond,

known as "disbonds" are not acceptable. In the method of the present invention, the intensity of the indication associated with a disbond decreases more slowly with decreasing excitation energy level than does the indication associated with a density difference. The indication associated with the disbond will remain detectable at lower energy levels than will the indication associated with the density difference. The size of an indication associated with a disbond will typically remain relatively unchanged with changes in excitation energy level, while the indication associated with a density difference will typically undergo a relatively marked change in size with changes in excitation energy level. The edge definition of an indication associated with a discontinuity in the bonded joint is more distinct than the edge definition associated with a density difference as the excitation energy level is changed. The edge of an indication associated with a density difference typically remains indistinct even at high excitation energy levels.

Analysis of the differences between the holograms of the fiber metal being tested and holograms of a reference fiber metal seal permit a disbond to be distinguished from a density difference. False positive findings and the resultant unwarranted high rejection associated with the conventional method are reduced by application of the method of the present invention.

An automated method of analysis wherein the holograms are digitized and the indications of material anomalies are compared to a library of transient indication behavior correlated to specific material anomalies is a possible refinement of the method of the present invention. Such a comparison would include, but not be limited to developing and comparing specific intensity values, gradients and changes in size and shape of the indications.

#### Example

A bonded joint in a fiber-metal abrasible seal for a turbine engine was analyzed according to the method of the present invention. Holograms of a reference abrasible seal are presented in FIGS 1A, 2A and 3A. The reference abrasible seal contained a known disbond in the joint. Holograms of the abrasible seal to be analyzed are presented in FIGS 1B, 2B and 3B. FIGS 2A and 2B are holograms generated at a first energy level, as discussed above. An indication of the disbond in the reference article is visible as a contrasting sharply defined area of FIG 2A. The contrasting area in FIG 2B would be regarded as an indication of a possible disbond in the test article.

FIGS 3A and 3B are holograms generated at a second energy level. In this example the second energy level corresponds to a scale reading forty percent lower than the scale reading associated with the first energy level. While the indication of the disbond in the reference hologram remains visible and sharply defined at the reduced energy level, there is no indication of a disbond in the hologram of

the test article shown in FIG 3B.

FIGS 1A and 1B are holograms generated at a third energy level. In the example, the third energy level corresponds to a scale reading forty percent above the scale reading associated with the first excitation energy level. Both the indication of the disbond in the reference article and the background are of higher intensity than in the hologram shown in FIG 2A, and the contrast between the indication and background is diminished relative to FIG 2A, but the indication is still well defined. The intensity of the indication in the hologram of the test article shown in FIG 1B has increased but the edge is diffuse and poorly defined.

The rates of change of the size, shape, edge definition and intensity of the indication of the disbond in the reference article are less than the rates of change of the size, shape, edge definition and intensity of the indication in the test article for the same change in excitation energy.

The findings that the indication in the hologram of the test article disappears at the low excitation energy level, has a poorly defined boundary at the high energy level, and that the size, shape, edge definition and intensity of the indication in the hologram of test article changes rapidly versus changes in excitation energy level than the indication of the disbond in the hologram of reference article all imply that the indication in the holograms of the test article are not caused by a disbond. Based on this analysis the test article was determined to be free of disbanded areas. This conclusion was confirmed by destructive testing of the test article.

The method of holographic analysis of the present invention allows indications of material anomalies to be categorized as to their probable cause. The method is useful as a non-destructive quality control test and provides improved reliability relative to conventional holographic inspection techniques due to the ability of the present method to distinguish between possible causes of holographic indications. This feature of the method allows false positive results and consequent unwarranted high rejection rate to be reduced.

While the best mode is described in terms of time average holography and analysis of bonded joints, it will be readily appreciated that the usefulness of the method disclosed is not limited to time average holography nor to bonded joint analysis. The method of the present invention may be applied to any technique of holographic interferometry and to the analysis of articles other than bonded joints which contain material anomalies other than joint disbonds. For example, the method might be applied to the analysis of a laminated structure to detect the presence of delaminations.

Although this invention has been shown and described with respect to detailed embodiments thereof, it will be understood by those skilled in the art that various changes in form and detail thereof may be made without departing from the spirit and scope of the claimed invention.

## Claims

1. A method of holographically analyzing an article, comprising,
  - generating a reference hologram of a reference article at a selected first energy level, said reference article having a known reference anomaly, said first energy level being chosen to reveal an indication of the reference anomaly, said indication being clearly defined and in strong contrast to the background,
  - generating a hologram of the article at the first excitation energy level, and
  - examining the hologram to determine if the hologram contains an indication of an anomaly in the article,
  - wherein the improvement comprises,
    - generating a second reference hologram of the reference article at a second excitation energy level, said second excitation energy level being lower than the first excitation energy level and being chosen to reveal an indication of the reference anomaly,
    - generating a second hologram of the article at the second energy level, if the first hologram of the article contains an indication of an anomaly in the article,
    - comparing each of the holograms of the article and each of the reference holograms to each other to detect differences between the holograms, and
    - analyzing the differences to more fully characterize the material and structural properties of the test article.

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FIG. 1A

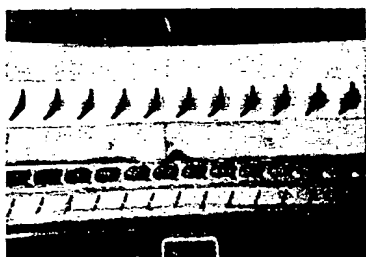


FIG. 1B

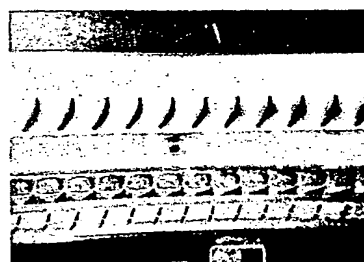


FIG. 2A

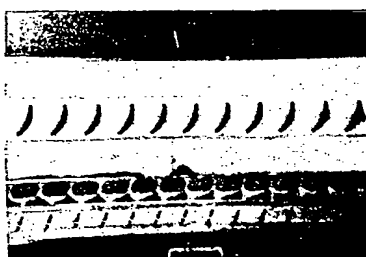


FIG. 2B

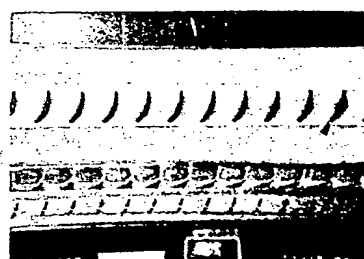


FIG. 3A

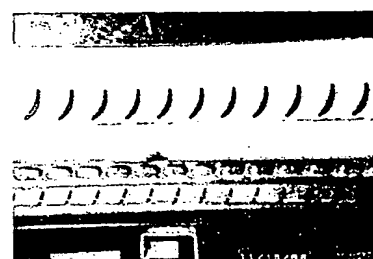
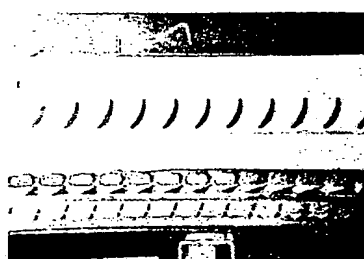


FIG. 3B



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(71) Applicant: **UNITED TECHNOLOGIES  
CORPORATION**  
United Technologies Building 1, Financial  
Plaza  
Hartford, CT 06101(US)

(72) Inventor: **Glinnis, Andrew F.**  
298 Cedar Ridge Drive  
Glastonbury Connecticut 06033(US)  
Inventor: **Larkin, Wesley F.**  
18 Dawn Drive  
South Windsor Connecticut 06074(US)

(74) Representative: **Waxweiler, Jean et al**  
**OFFICE DENNEMEYER S.à.r.l.** P.O. Box 1502  
L-1015 Luxembourg(LU)

(54) Transient holographic indication analysis.

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FIG. 1A

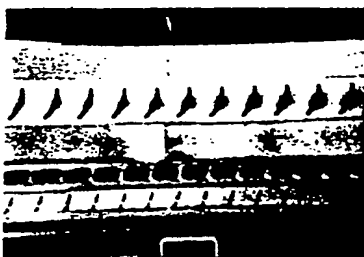
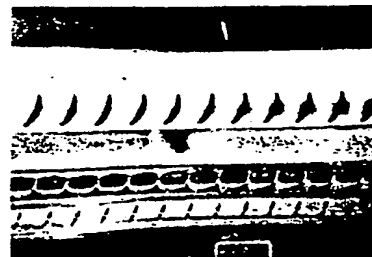


FIG. 1B





European Patent  
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## EUROPEAN SEARCH REPORT

Application Number

EP 88 63 0130

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A,D	US-A-3 645 129 (R.M. GRANT) ---	1	G 01 B 9/021
A	DE-A-3 240 756 (UNITED TECHNOLOGIES CORP.) * abstract; page 6, passage 2 *; & US - A - 4408881 (Cat. A,D) ---	1	
A	US-A-3 548 643 (E.N. LEITH et al.) * abstract; claims * ---	1	
A	US-A-3 762 215 (C.C. ALEKSOFF) * whole document * ---	1	
A	US-A-3 545 259 (R.M. GRANT) * whole document * ---	1	
A	DE-A-1 947 201 (BROWN, BOVERI & CIE.) * page 1 * ---	1	
A	DE-B-2 107 101 (GCOPTRONICS, INC.) * columns 1,2 * ---	1	
A	DE-A-2 354 909 (ROLLS-ROYCE (1971) LTD.) * claims 1,9 * ---	1	<b>TECHNICAL FIELDS SEARCHED (Int. Cl.4)</b>  G 01 B 9/021 G 01 N 21/88 G 03 H 1/00
A	AUTOMATIC WELDING vol. 39, no. 1, January 1986, pages 31-34, Abington, Cambridge, GB; L.M. LOBANOV et al.: "Holographic inspection of the quality of welded joints in polymer substances" * page 32 * --- -/-	1	
The present search report has been drawn up for all claims			
Place of search <b>BERLIN</b>		Date of completion of the search <b>13-02-1990</b>	Examiner <b>KOEHN G</b>
<b>CATEGORY OF CITED DOCUMENTS</b>			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document	

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 4)
A	M.A.N. FORSCHEN-PLANEN-BAUEN no. 14, 1983, pages 18-25; Augsburg, DE; B. BREUCKMANN: "Holografie - neue Möglichkeiten in der Messtechnik" * page 24 * -----	1	
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
The present search report has been drawn up for all claims			
Place of search BERLIN		Date of completion of the search 13-02-1990	Examiner KOEHN G
<b>CATEGORY OF CITED DOCUMENTS</b>			
<b>X</b> : particularly relevant if taken alone <b>Y</b> : particularly relevant if combined with another document of the same category <b>A</b> : technological background <b>O</b> : non-written disclosure <b>P</b> : intermediate document			
<b>T</b> : theory or principle underlying the invention <b>E</b> : earlier patent document, but published on, or after the filing date <b>D</b> : document cited in the application <b>L</b> : document cited for other reasons ..... <b>&amp;</b> : member of the same patent family, corresponding document			

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